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## Current Trends in Smart Weapons

A Technical Assessment

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Over the last thirty years or so major advances have been made in the development of seekers and sensors for use on smart weapons. The American public had its first look at "smart weapons" when they watched guided bombs used against targets in North Vietnam. Their most recent look has been at guided bombs being dropped on Iraq. However, during this time many advanced technologies have evolved that provide seekers and sensors for smart weapons that operate in bands of the electromagnetic spectrum that are not visible to the human eye. Therefore, they do not send back information (pictures) that can be used on television. This assessment will review the technologies currently being used or under development for the seekers and sensors of smart weapons, and identify trends for the future.

Before such a discussion can proceed it may be useful to establish a set of common definitions. For the purpose of this paper the following definitions will apply:

**Sensor** - a device that can detect a target and initiate a warhead. A sensor does not provide guidance and control to a weapon. The munition must be placed close to the target by means other than the sensor. The sensor only determines that a target is in the lethal range/ orientation of the munition and activates the weapon's warhead. Sensors are normally used in "shoot-to-kill" weapons.

**Seeker** - a device that employs a sensor to acquire a target and provide guidance information that is used to maneuver a weapon to lethally intercept a target. Seekers are normally used in "hit-to-kill" systems.

**Smart Weapon** - The term "Smart Weapon," also referred to as "precision guided munitions (PGM)," is often applied to weapons that have a wide range of attributes. It is a generic term that applies to any of the following three classes of weapons:

**Guided Munitions** - these munitions will have an operator in the loop to select the target and often will assist in guidance of the weapon. These munitions are usually one-on-one munitions, i.e., a specific munition is designated to engage a specific target, and are often referred to as man-in-the-loop systems. Radar command guided weapons also fall under this classification.

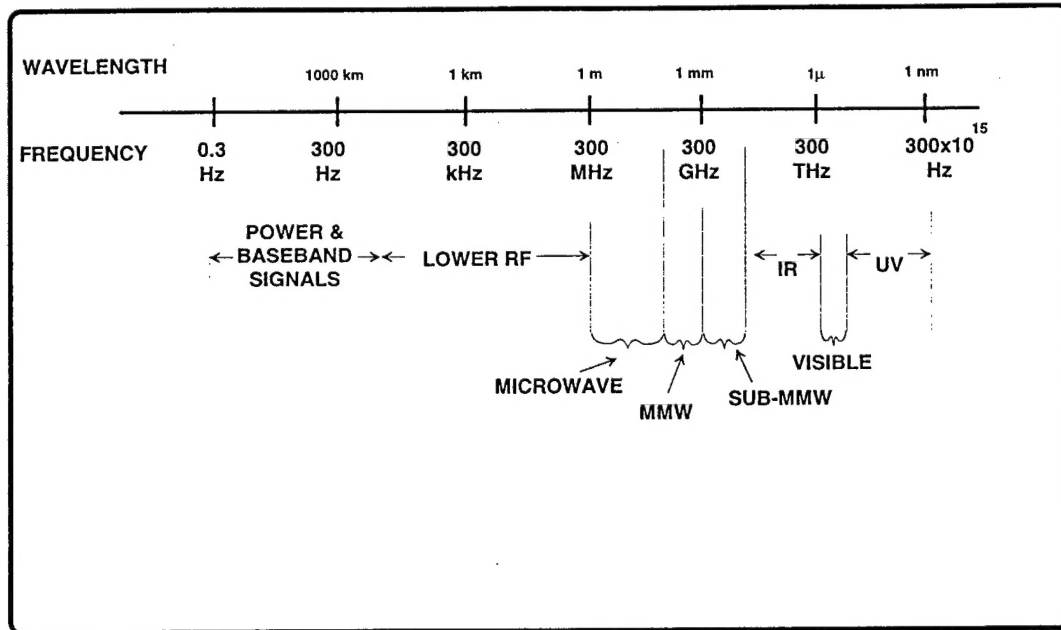
**Smart Munitions** - this class of munitions operates autonomously to search, detect, identify, select, and engage targets. They have limited target discrimination capability and do not require an operator in the loop. These munitions may be delivered to a selected area by a "carrier" such as a munition dispenser, rocket, missile, or projectile, then are dispensed and begin their target search.

**Brilliant Munitions** - brilliant munitions will be the next generation of smart weapons. They will operate autonomously to search, detect, identify, select, and engage targets. These munitions will be capable of identifying and engaging specific classes of targets. They will have the built-in flexibility to effectively engage and prioritize a variety of targets. -

Weapons do not always fall neatly into one classification or another. An example of this is an aircraft-launched missile with a radar seeker. If the pilot selects the target and locks the

missile onto it before firing, then the system has a man-in-the-loop and fits the definition of a guided munition. If the pilot uses a lock-on-after-launch option, fires the missile into an area believed to contain a group of targets, and the missile selects one of the group and attacks it, then the missile is classified as a "smart munition."

The first smart weapons were what is commonly referred to as "smart bombs." These bombs were guided from release to impact by an individual who, using a data link to the bomb, could see the desired point of impact and could provide input to the guidance and control system to guide the bomb to the desired point. Some of the more advanced smart weapons being fielded today are totally autonomous. They are dispensed over a target area, and using seekers, search a large area, find and identify a target, then attack the target. Operations in the autonomous mode require the use of different parts of the electromagnetic spectrum than the visible light spectrum used in the earlier systems. Figure 1 shows the different parts of the electromagnetic spectrum that are used in different types of sensors/seekers.



**Figure 1. Electromagnetic Spectrum**

The vast majority of current sensors/seekers use only a limited number of small bands of the electromagnetic spectrum. Most common of these are:

1. Radio Frequency (RF): the most common RF seeker is active radar; however, some weapons use a passive millimeter-wave (MMW) sensor.
2. Infrared (IR): the vast majority of sensors/seekers that use IR use passive imaging (focal plane arrays) to sense the heat given off by objects. Some of the systems under development use an active IR imaging technology known as LADAR that functions similar to radar and gives excellent 3D imaging.

3. Semiactive laser (SAL): This is a seeker that homes on the reflected energy of a laser that is directed at a target. This type system requires a man-in-the-loop to aim and fire the laser.

Other types of sensors/seekers that are being used are:

1. Acoustic: these sensors use a series of microphones that "hear" the noise created by potential targets and provide the munition with rough target acquisition and target array assessment. These can be expected to be found in combination with other sensors/seekers that will provide the resolution needed for the terminal end of the attack.
2. Seismic: seismic sensors "feel" the vibrations of the ground created by moving targets.
3. Magnetic: magnetic sensors are most commonly used for proximity fuzing sensors. They sense the magnetic field created by large targets and determine the best time to set off the weapon's warhead.

The selection of a smart weapon's sensor/seeker technology is driven by the mission requirements for the system. Several things must be considered when selecting a sensor/seeker package for a weapon system. Some of the major considerations are:

- Can the seeker/sensor, the required data processing capability, and power supply be packaged to fit into the weapon?
- Is the target permanently located or is it mobile?
- What kind of signature does the target have and what is the background signature in which the target is expected to be found.
- Does the technology exist to observe these signatures in a tactical environment and under the weather conditions in which the weapon is to be employed?
- Will the seeker/sensor package work in the countermeasure environment expected to be encountered?

Another form of guidance that is often used in "smart weapons" is the global positioning system (GPS) and inertial navigation systems (INS). These systems are often used together and are then referred to as GPS/INS. GPS uses a series of satellites in orbit around the earth - transmitting position data. A GPS receiver can receive this data and calculate its position. INS uses a series of internal gyros and electrical processors to calculate position by measuring direction and velocity of movement from a known point over time. INS loses some of its

accuracy over time. Combining GPS with INS allows periodic updates of position with the very accurate GPS data, and uses INS for navigation between GPS updates. Together they provide a reliable and efficient system to navigate to a given point in space.

Given the definitions above and a knowledge of the sensor/seeker technologies available, a lot can be determined about trends by grouping currently fielded systems and systems under development by their primary guidance system: Man-in-the-Loop, GPS/INS, and Non-Man-in-the-Loop (Sensor/Seeker). Table 2 presents such a grouping. As with definitions, some systems fit under more than one heading. An example of this is EFOG-M. EFOG-M has a fiber-optic cable linking it with the soldier controlling it, GPS to allow navigation to the target area without requiring operator control for its entire flight, and a terminal seeker. The seeker allows the operator to lock the missile on a target and turn over the terminal leg of the attack to a seeker, while he takes control of another missile that is already approaching the target area using GPS guidance. In such cases the system has been grouped by its primary guidance system, that being the one that makes the system different from others or that is its primary mode of operations. Some systems have more than one mode of operation that are "either/or" and are not used together. An example of this is the PGMM. It has two modes of operation: IR seeker (fully autonomous) and laser designation (man-in-the-loop). In these cases the system is grouped under both headings.

**Table 1. Breakdown Of Weapons By Guidance**

Man-In-The-Loop/ Radar Command Guided	GPS / INS	Non-Man-In-The-Loop (Sensor/Seeker)	
		Smart Weapon	Smart Submunition
SLAM AMRAAM MAVERICK AGM 142 GBU 15 / AGM-130 HELLFIRE II HELLFIRE LONGBOW COPPERHEAD JAVELIN STAFF STINGER EFOG-M JSOW UNITARY PGMM THAAD PATRIOT TOW	TOMAHAWK III JDAM JSOW (Baseline) HARPOON (Terminal seeker)	HARM PGMM (IR) AMRAAM HELLFIRE LONGBOW	SADARM BAT BAT P3I WAM LOCAAS SFW/BLU-108 DAMOCLES

The above groupings clearly indicate three major trends in smart weapon development:

1. The majority of systems still use a man-in-the-loop system in conjunction with some type of terminal sensor/seeker.

2. The use of GPS/INS is increasing. It is being incorporated in new systems and in upgrades to older systems. GPS guidance is also included in or is planned for several systems that carry, or have the potential to carry, smart submunitions. These include a variety of different types of systems such as Tomahawk, JSOW, ATACMS, ER-MLRS.
3. Smart submunitions are non-man-in-the-loop and use a large variety of sensors/seekers to locate and engage targets. The vast majority of these systems use a suite of sensors/seekers rather than a single sensor/seeker. All of the P3I programs incorporate this capability.

A review of the man-in-the-loop systems reveals that many of them are aircraft-delivered weapon systems or systems used by front line troops. The use of man-in-the-loop technologies in these types of systems make sense. With aircraft delivered systems and front line systems there is a man in position to observe directly, or with some type of sensor, the exact location and nature of the target. This is invaluable when specific, individual targets are to be engaged. Modern man-in-the-loop systems tend to require operator assistance only for initial target designation, with autonomous target tracking capability.

The second type of system is the GPS/INS guided system. These are excellent for targets that are permanently located or that rarely move. Current GPS technology allows for delivery accuracy of less than 15 meters. This technology is being incorporated within some of the newest systems and within upgrades to some of the older systems. When coupled with a data link and/or a terminal seeker this is an very accurate way to deliver a munition. Up until this time one drawback to GPS technology has been the inability to update the target location during the long planning and flight time of many of the systems. New intelligence and communication technologies that allow quick target location update to weapons in flight will make this a more flexible and common guidance system.

When non-man-in-the-loop systems are reviewed, the first thing that is noticed is that the preponderance of these systems are smart submunitions. A further review will disclose that all of the smart submunitions are classified within this group. A close look at the sensor/seeker technologies used in these submunitions reveals that most use multispectral sensors/seekers. All of the multispectral sensor/seeker weapons are smart submunitions except for variants of the Stinger missile which use an ultraviolet seeker, in addition to its IR seeker, for aim point selection.

This review leads to some conclusions on trends in smart weapon:

1. When the target is very specific, man-in-the-loop is very likely to be the type system chosen. This allows the operator to engage a target that is presenting a real-time threat or to hit a target that is in the near proximity of structures, equipment, or individuals that it is not desirable to damage or injure.

2. GPS/INS is becoming more common and is often the choice guidance system to engage targets that do not move or that move infrequently. As the ability to update target location and pass the information to the weapon quickly becomes more feasible, the use of GPS for guidance will increase.
3. The use of multispectral sensors/seekers is becoming more common. The autonomous systems that must find and recognize targets without the input of an operator tend to use this technology. As more smart submunitions are developed, countermeasure capabilities improved, and older systems are upgraded, this type sensor/seeker suite will become more common.

Sensor/seeker technologies continue to advance at a pace that could not have been envisioned by most people thirty years ago. This pace is continuing to increase. As new technologies are developed and current technologies are advanced the capabilities of non-man-in-the-loop weapon systems can be expected to rapidly advance and exceed the capabilities of current and past man-in-the-loop systems.

## ACRONYMS

AGM	Air-to-Ground Missile
AMRAAM	Advanced Medium Range Air-to-Air Missile
ATACMS	Army Tactical Missile System
BAT	Brilliant Anti-armor Submunition
EFOG-M	Enhanced Fiber Optic Guided Missile
ER-MLRS	Extended Range-Multiple Launch Rocket System
GBU	Guided Bomb Unit
GPS	Global Positioning System
HARM	High-speed Anti-Radiation Missile
INS	Inertial Navigation System
IR	Infrared
JDAM	Joint Direct Attack Missile
JSOW	Joint Standoff Weapon
LADAR	Laser Detection and Ranging
LOCAAS	Low Cost Autonomous Attack Submunition
MMW	Millimeter Wave
PGM	Precision Guided Munition
PGMM	Precision Guided Mortar Munition
RF	Radio Frequency
SADARM	Sense-and-Destroy Armor
SAL	Semi-Active Laser
SFW	Sensor Fuzed Munition
SLAM	Standoff Land Attack Missile
STAFF	Smart Target Activated Fire-and-Forget
THAAD	Theater High Altitude Area Defense
TOW	Tube-launched, Optically tracked, Wire guided
WAM	Wide Area Munition